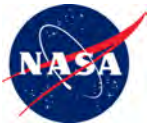




Observing System Simulations in Support of ASCENDS Mission Requirements Definition

S. R. Kawa*, D. F. Baker, A. E. Schuh, S. M. Crowell, P. J. Rayner, D. Hammerling, A. M. Michalak, Y. Shiga, J. Wang, J. Eluszkiewicz, L. Ott, T. S. Zaccheo, J. B. Abshire, E. V. Browell, B. Moore III, D. Crisp, and the ASCENDS Requirements Definition Team

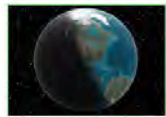
- ASCENDS Overview
 - instrument simulation
- OSSEs
 - signal detection sensitivity
 - flux inversions
 - atmospheric state
- Summary



ASCENDS

ACTIVE SENSING OF CO₂ EMISSIONS OVER NIGHTS, DAYS, AND SEASONS (ASCENDS)

Launch: ~~2013-2016~~ Mission Size: Medium



CO₂ measurements:
day and night, all
seasons, all latitudes



Inventory of global
CO₂ sources and
sinks

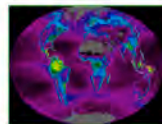
Connection between
climate and CO₂
exchange



Improved climate
models and predictions
of atmospheric CO₂



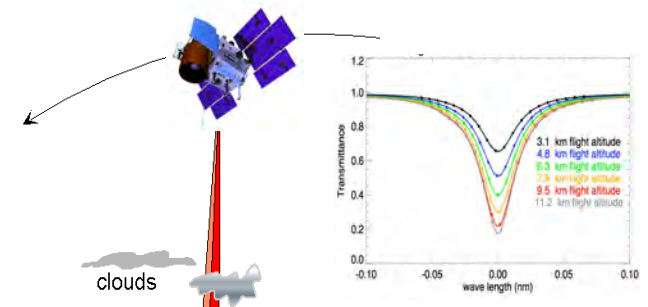
Identification of human-
generated CO₂ sources
and sinks to enable
effective carbon trading



Closing of the carbon
budget for improved
policy and prediction

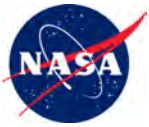
Earth Science and Applications from
Space: National Imperatives for the
Next Decade and Beyond

Space-based Lidar for Atmospheric CO₂



“Mixing ratio (CO₂) needs to be measured to a precision of 0.5 percent of background (slightly less than 2 ppm) at 100-km horizontal length scale over land and at 200-km scale over open oceans.”

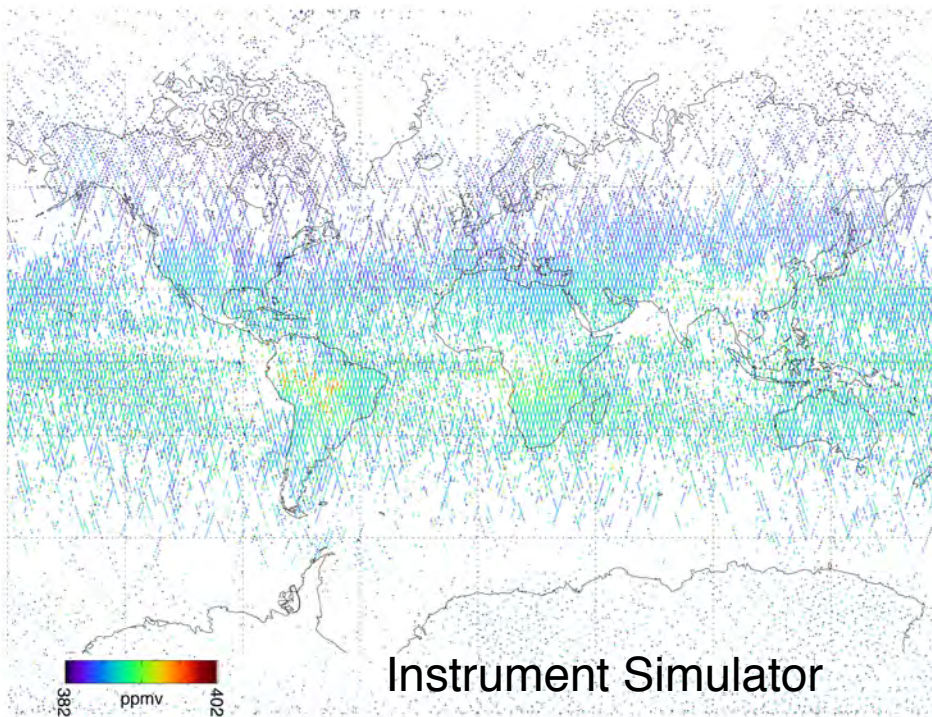




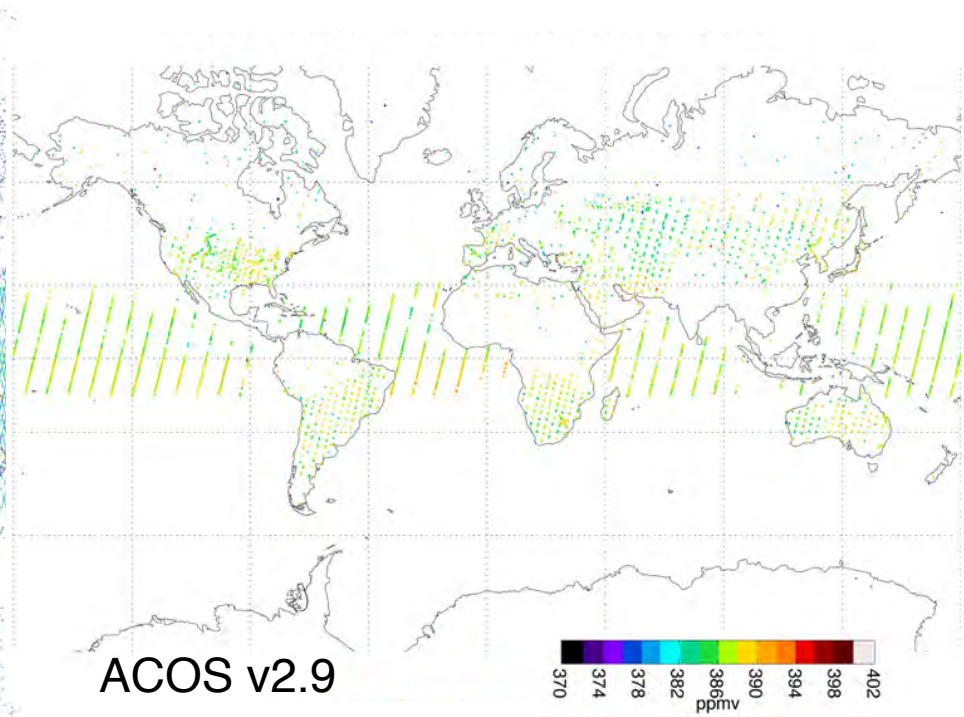
Coverage and Errors

- Day/night all-latitude, land/ocean coverage
- Greatly reduced cloud/aerosol biases
- Potential for improved vertical resolution

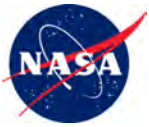
ASCENDS: N = 54423



GOSAT: N = 9306



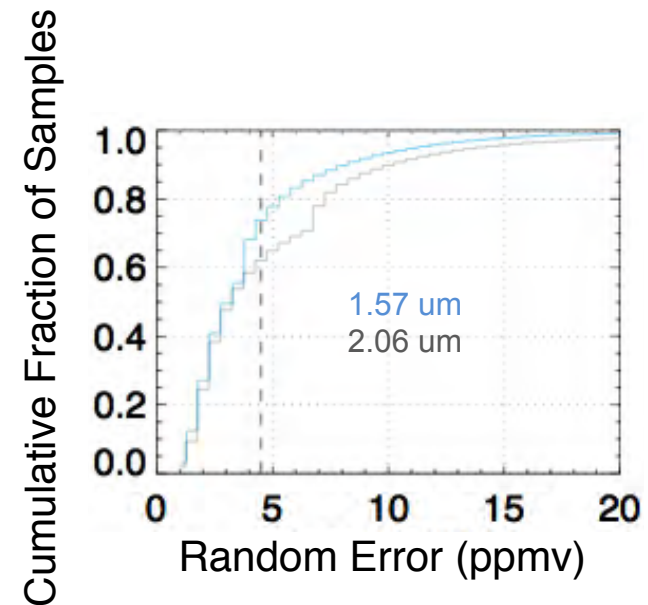
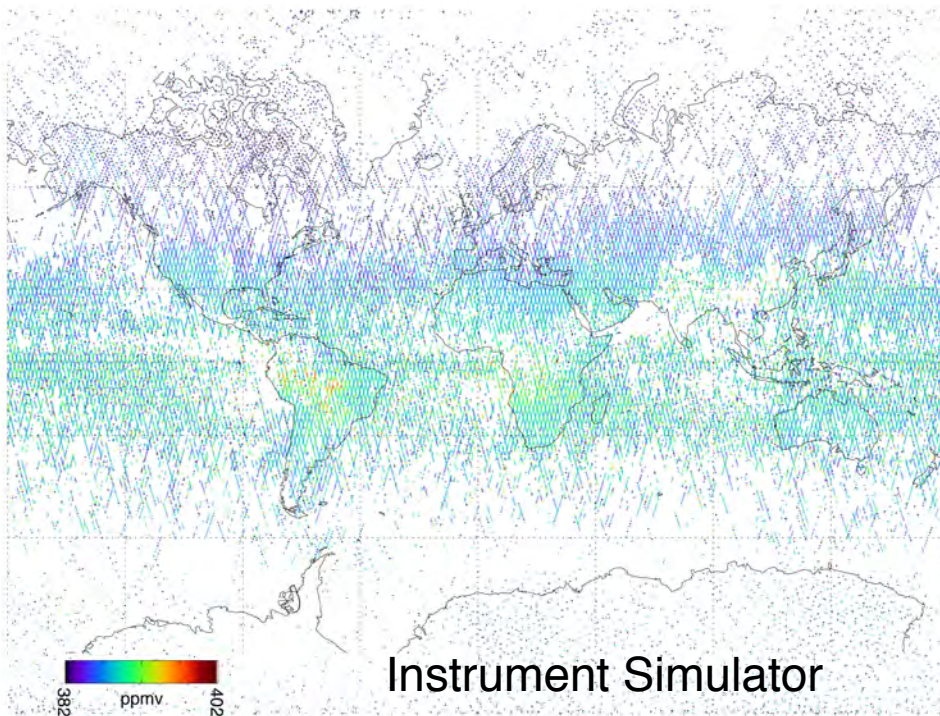
2010-09-01 – 2010-09-16



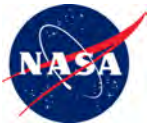
Coverage and Errors

- Realistic ASCENDS random errors
- Scaled globally using observed clouds, aerosols, and reflectances

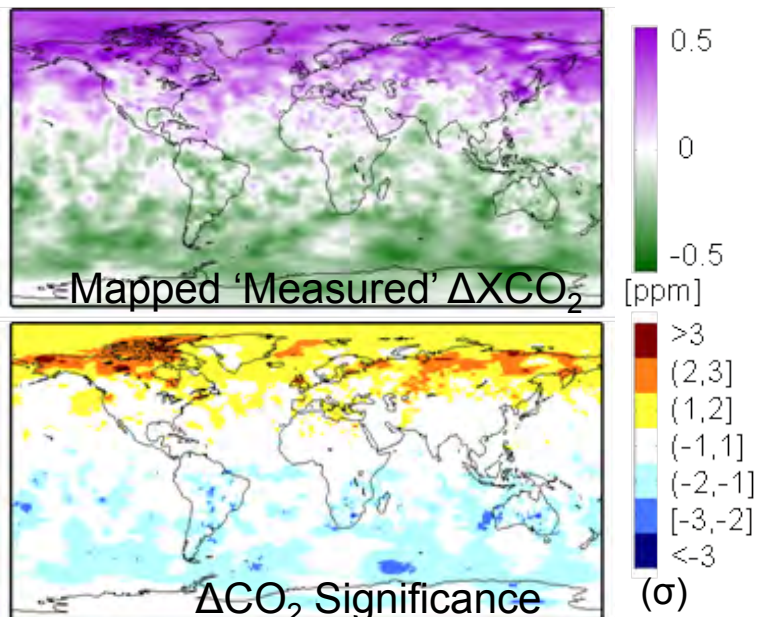
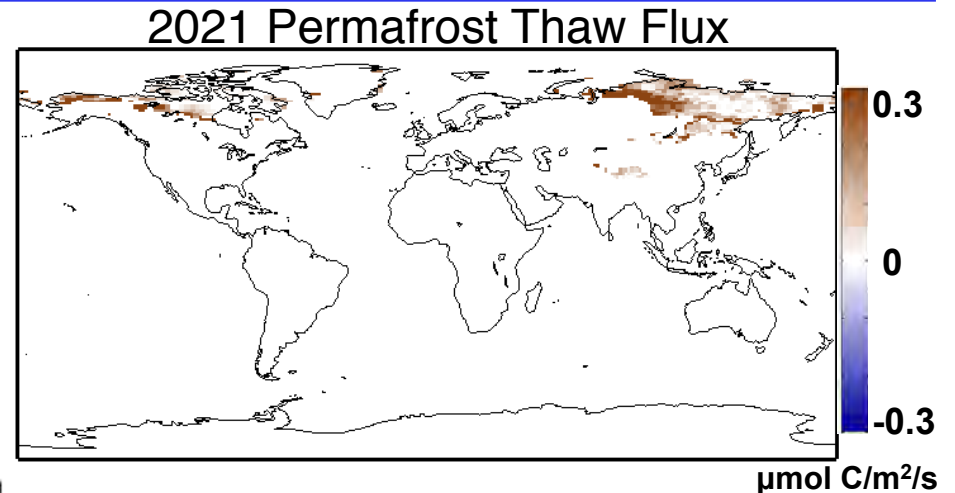
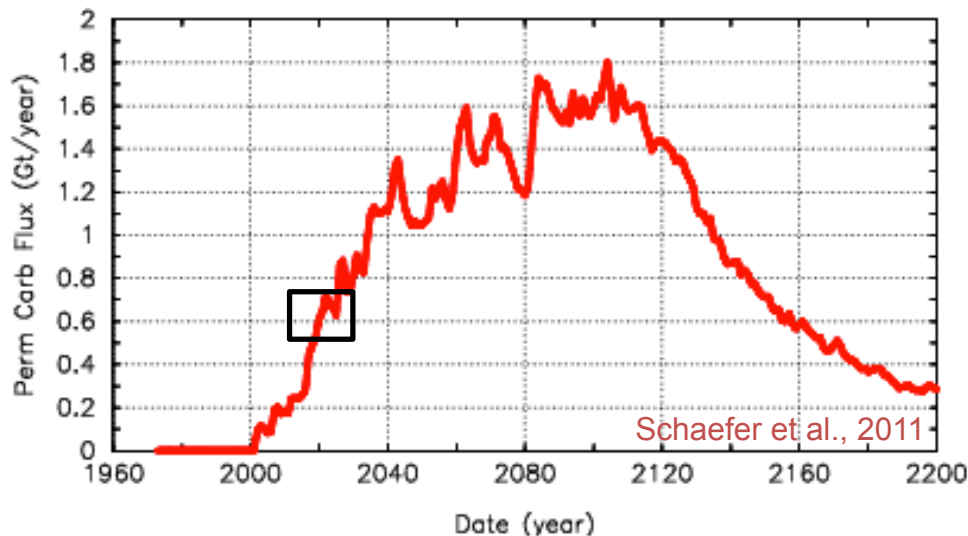
ASCENDS: N = 54423



2010-09-01 – 2010-09-16



Signal Detection Sensitivity

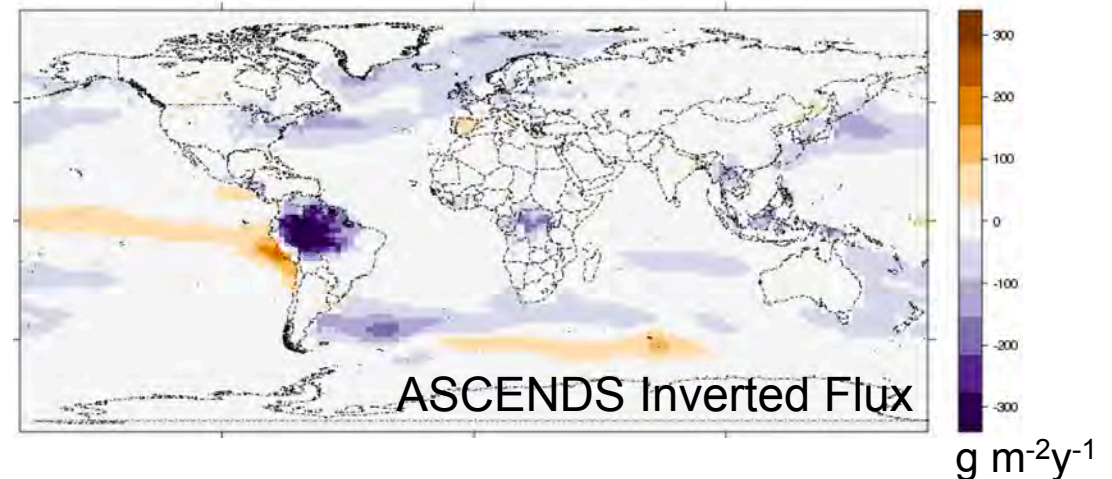
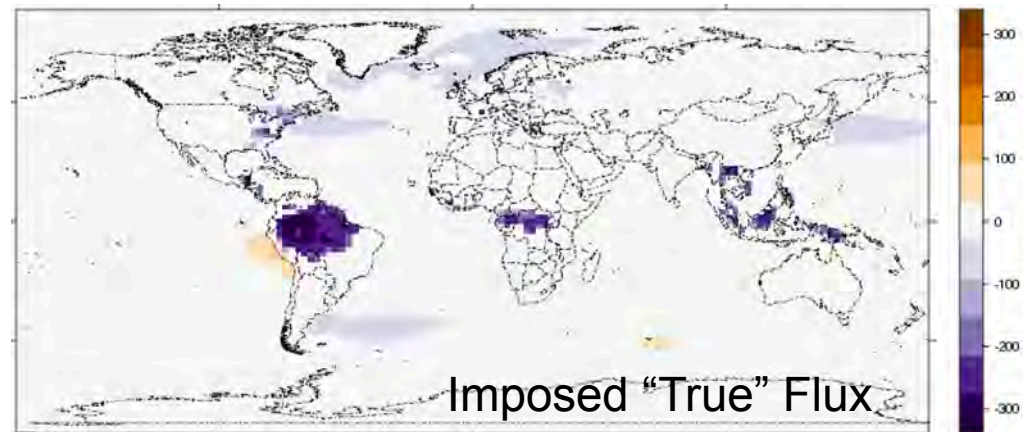


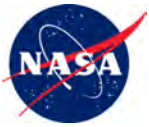
- Change due to permafrost thawing readily detectable, likely attributable, with nominal ASCENDS precision.
- Similar tests indicate:
 - fossil fuel emission shift detectable depending on magnitude
 - Southern Ocean flux difference detectable with more averaging, higher precision



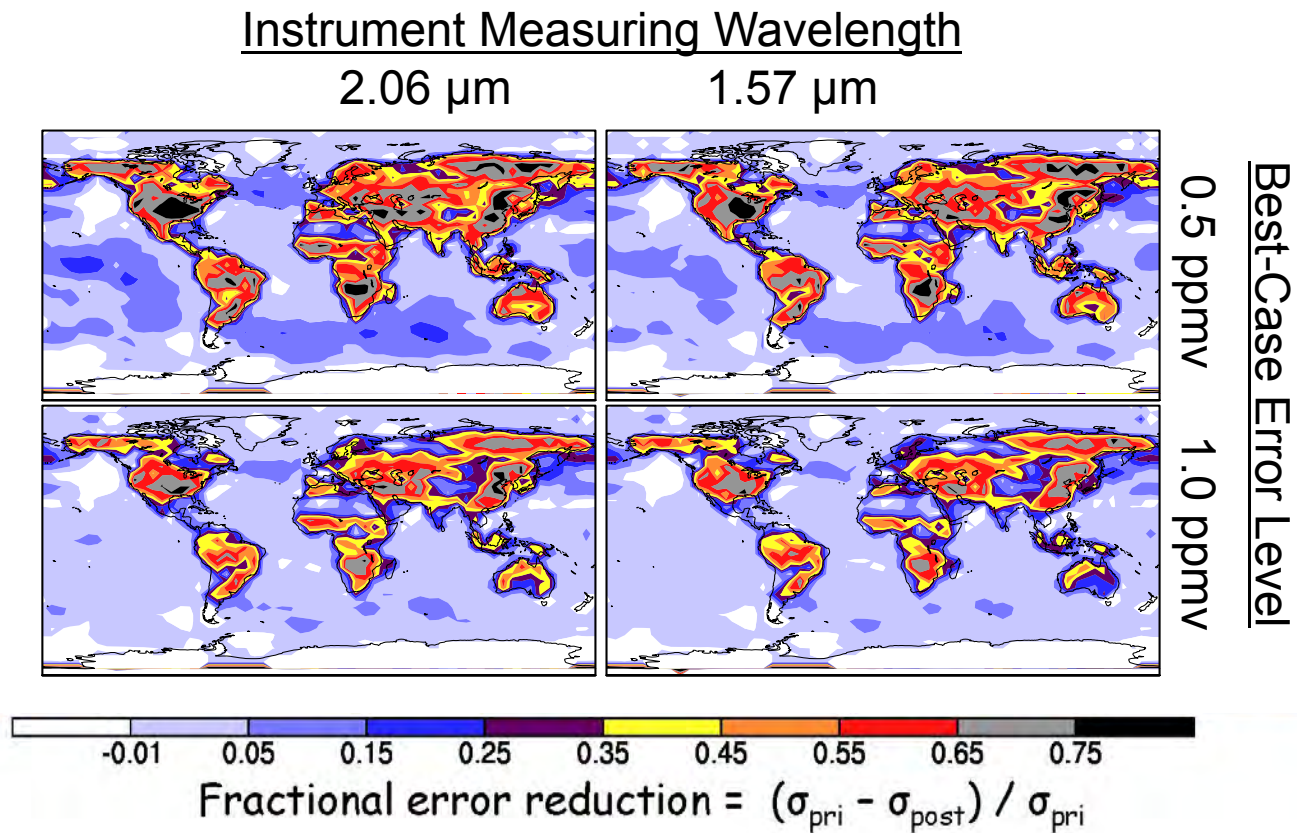
Inversion of Ecosystem Sink

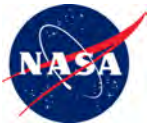
- Test ability to infer bias in ecosystem exchange of CO_2 , i.e., example of possible 'missing sink' for atmospheric carbon.
- Annual inversion captures most of the large land sink features although somewhat noisier than "truth."
 - assumed ASCENDS random error: 1 ppmv (@ 2.0 μm)





Flux Inversion OSSEs



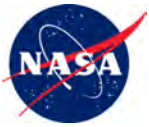


Instrument Inversion Tests

Fractional Error Reduction in CO₂ Flux Inversion for 1 Year

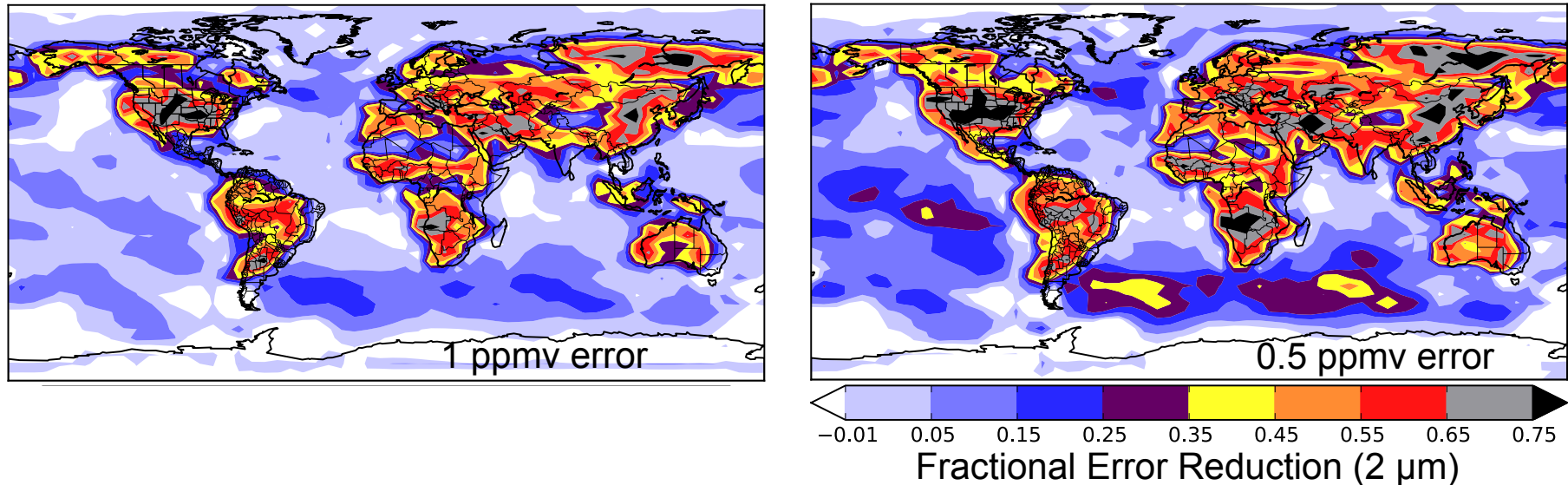
<div><div>Avg Kernel</div><div>Nominal error (ppmv)</div></div>	2.06 μm	1.57 μm +10 pm	
0.5	0.49 0.51 0.17	0.47 0.49 0.13	Global Land Ocean
1.0	0.41 0.43 0.13	0.39 0.41 0.10	

- All considered instrument models produce large flux error reductions
- Inversions inform instrument trade-space decisions

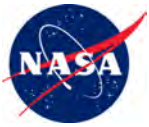


Model Dependence

OU/UMelbourne Flux Inversion

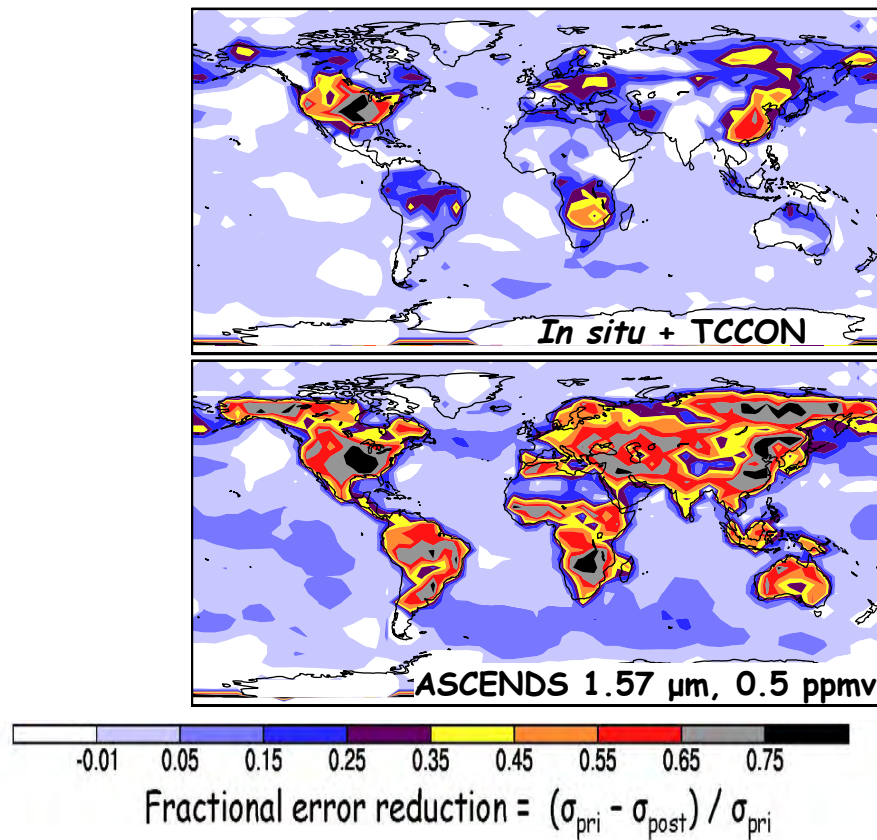


- Spatially similar but quantitatively different error reductions given same inputs with different inversion methodology and transport
- Answer depends on model specifics
- Suite of models considered, including regional

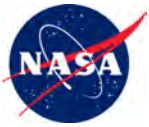


Observing Systems Comparison

Flux Error Fractional Reduction



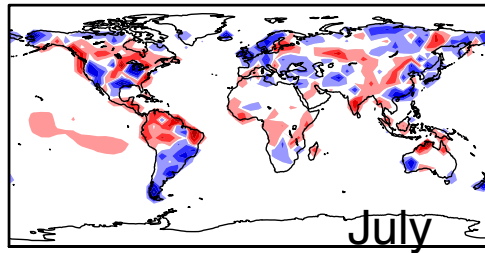
- ASCENDS provides large increase in error reduction compared to existing observations
 - limited enhancement relative to expected OCO-2 with random errors only
- Further progress via reduced bias compared to passive sensors



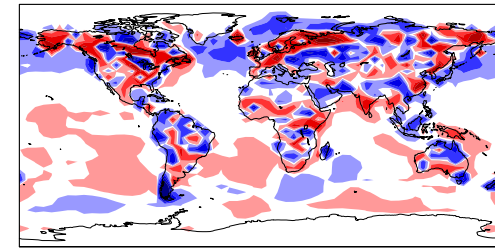
Flux Shift Resulting from Bias



Random mmt error only



OCO-2 bias estimated from GOSAT



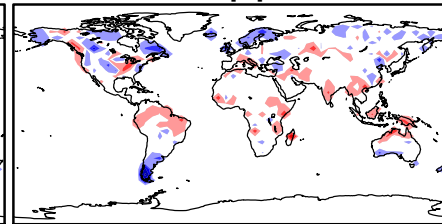
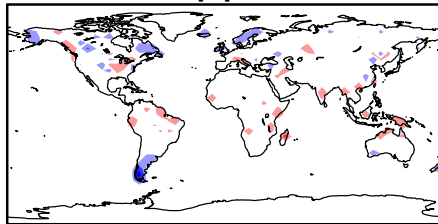
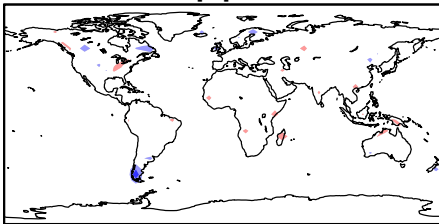
ASCENDS
bias form

0.25 ppmv

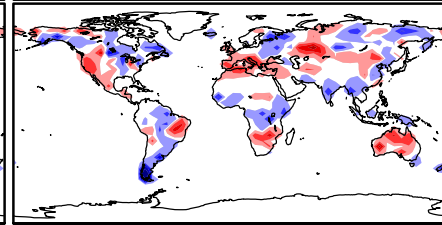
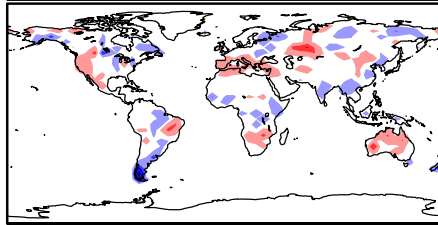
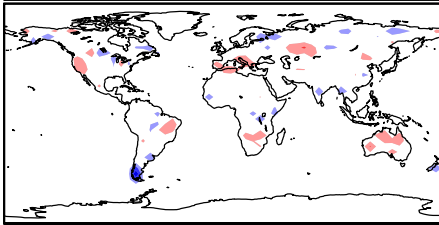
0.5 ppmv

1.0 ppmv

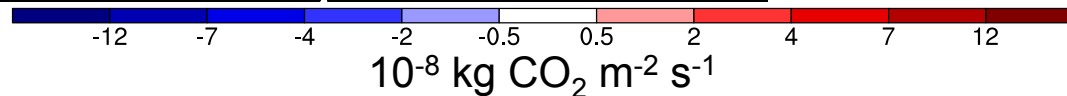
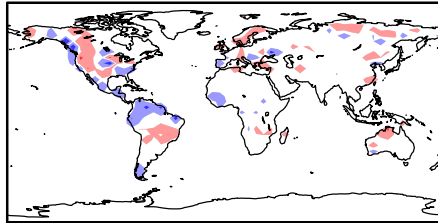
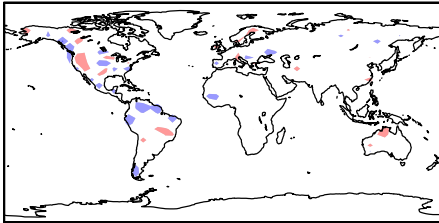
SZA bias

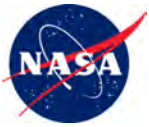


Signal bias



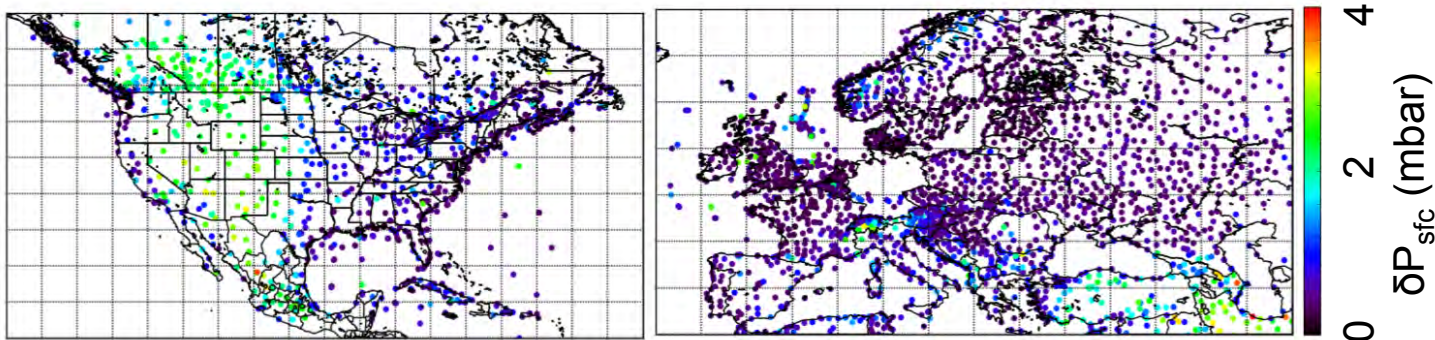
Cloud bias



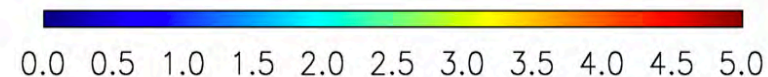
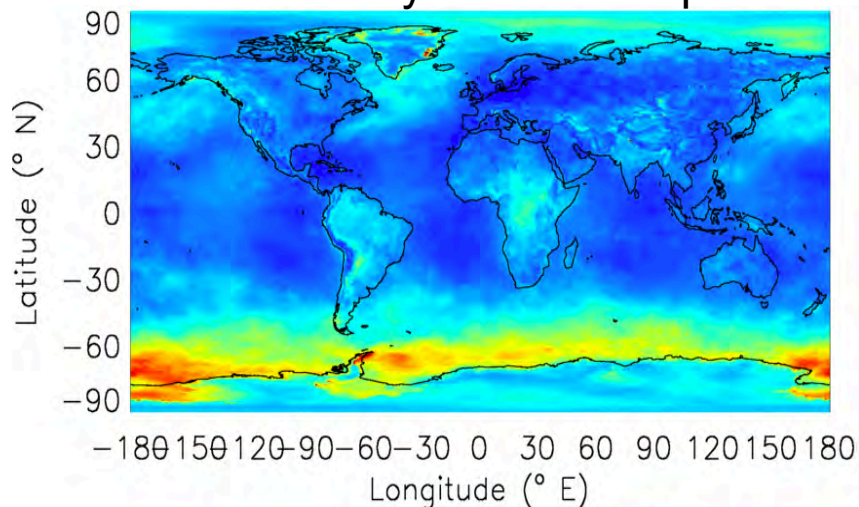


Atmospheric State

RMS Model-Data Difference



3-Model Analysis Intercomparison



P_{sfc} 90% Confidence Threshold (mbar)

- Dry air surface pressure is required to produce CO_2 column dry mole fraction.
- Surface pressure uncertainty is about 1-2 mbar from met analyses.
→ Requirement to measure O_2 ?
- Plus, impact of T, H_2O profile uncertainties can be substantial.

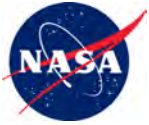


Summary

- Observing system simulation experiments comprise a valuable framework
 - ASCENDS data will be capable of resolving several key hypotheses in carbon cycle science
 - Inverse models show significant flux uncertainty reduction, as well as relative performance scaling for varying instrument configurations
 - Using several models to establish robustness
- Large CO₂ flux improvement expected relative to current capability
 - Further benefit from expected lesser bias errors than OCO-2
- Requirement for co-aligned O₂ measurement debated
 - Atmospheric state uncertainty not negligible

Next Steps

- Producing ASCENDS mission white paper for community reference
 - Toward establishing L1 measurement requirements
 - Candidate for next decadal survey
 - Continuing assessments, e.g., bias error impacts



Acknowledgements

- M. Vaughan, NASA LaRC
- R. Menzies, G. Spiers, NASA JPL
- J. Mao, C. Weaver, H. Riris, Y. Liu, X. Sun, J. Collatz, NASA GSFC
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